Norfolk CSO Sediment Remediation Project
Five-Year Monitoring Program

April 1999 Monitoring Report

Elliott Bay/Duwamish Restoration Program

Prepared for the
Elliott Bay/Duwamish Restoration Program Panel
by the
King County Department of Natural Resources

Panel Publication 22

August 1999

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August 1999

Individuals and organizations needing further information about the Elliott Bay/Duwamish Restoration Program should contact the Administrative Director at the following address and telephone number:

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The Panel of Managers holds regularly scheduled meetings that are open to the public. Technical Working Group and committee meetings are scheduled on an as-needed basis, and are also open to the public. Meetings are generally held at the National Oceanic and Atmospheric Administration, National Marine Fisheries Service - Regional Directorate Conference Room, Building 1, 7600 Sand Point Way NE, Seattle. The Panel recommends that you contact the Administrative Director at the above phone number to confirm meeting schedules and locations. The panel also holds periodic special evening and weekend public information meetings and workshops.

General Schedule for Panel and Committee Meeting Dates

Panel: quarterly, first Thursday of January, April, July, October, 9:30 A.M. - 12:30 P.M.
Habitat Development Technical Working Group: third Thursday of every month, 9:30 A.M. - 12:30 P.M.
Sediment Remediation Technical Working Group: scheduled as needed.
Public Participation Committee: scheduled as needed.
Budget Committee: scheduled as needed.

Environmental Review of Specific Projects

Formal hearings and comment periods on appropriate environmental documents for proposed sediment remediation and habitat development projects will be observed. Please contact the Administrative Director for more information.

This information is available in accessible formats on request at (206) 296-0600 (voice) and 1-800-833-6388 (TTY/TDD users only).

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1 INTRODUCTION

This report presents the results of the first sampling event of a five-year monitoring program at the Norfolk combined sewer overflow (CSO) sediment remediation site. The purpose of the five-year program is to monitor sediment placed as backfill material at the site for potential recontamination from CSO and other discharges. The first sampling event occurred in April 1999, within the first month after completion of remedial activities, and was intended to collect baseline data on the chemical characteristics of the sediment used as backfill material. Included in this report are a project background, descriptions of sampling and analytical methodologies, analytical results, and a quality assurance review of the analytical data.

1.1 Project Background

Sediment remediation at the Norfolk CSO site was undertaken to partially fulfill sediment remediation requirements of a 1991 Consent Decree, which defined the terms of a natural resources damage agreement between King County (along with the City of Seattle) and federal, state, and tribal natural resources trustees. The Norfolk CSO site was chosen by the Elliott Bay/Duwamish Restoration Program (EBDRP) Panel as one of four sites prioritized for potential sediment remediation.

A site characterization and cleanup study was performed in 1994 and 1995, and the cleanup study report was issued in 1996 (EBDRP, 1996). Chemicals of concern at the site included mercury, 1,4-dichlorobenzene, bis(2-ethylhexyl) phthalate and polychlorinated biphenyls (PCBs), all present at concentrations exceeding State of Washington Sediment Management Standards (SMS) sediment chemical criteria values that define the cleanup screening levels. PCB "hot spot" concentrations at the site also exceeded Toxic Substances Control Act (TSCA) limits for hazardous waste disposal.

Site remediation began in early February 1999 and was completed by late March 1999. Remedial activities consisted of dredging and disposal of contaminated sediment and backfilling the dredged area to original grade with clean sediment from the Duwamish River Turning Basin. Contaminated sediments were removed from the site by mechanical dredge and dewatered on shore in a containment area first arranged to segregate batches about 50 cubic yards (cy) in size and later reconfigured to handle larger batches.

Sediment samples were collected daily from each 50-cy batch and analyzed for PCB concentrations to determine the appropriate disposal destination. Sediments with a PCB concentration greater than 45 parts per million (ppm) were transported to a Subtitle C landfill in Arlington, Oregon for disposal. Sediments with a PCB concentration less than 45 ppm were transported to a Subtitle D landfill in Bremerton, Washington for disposal.

A total of 5,190 cy of sediment was removed during the remediation, of which approximately 1,900 cy of sediment was transported to the Subtitle C landfill as hazardous waste. Sediment was generally removed to a depth of three feet, however, remediation in the PCB hot spot areas required removal of sediment up to nine feet in depth.

Confirmational testing subsequent to dredging activities indicated that, in some of the deepest-dredged areas, sediments were left in place that contained PCB concentrations greater than SMS chemical criteria. Discussions with project oversight personnel from the EBDRP Panel and State of Washington Department of Ecology (Ecology) determined that, at a depth of nine feet below original grade, these PCB-contaminated sediments could be left in place.

Clean backfill sediment was obtained from the Duwamish River Turning Basin during normal, maintenance dredging operations by the Army Corps of Engineers (ACOE). Data collected by the Corps prior to maintenance dredging indicated that this material was suitable for use as backfill material (ACOE unpublished data, 1998). A sample was also collected from the Turning Basin sediment after it was placed on a barge and just prior to backfilling activities. Analytical results from this sample confirmed the suitability of the sediment as backfill material (King County unpublished data, 1999). No organic chemicals were detected in the sample and metals were detected at levels indicative of natural, area-wide crustal sediment concentrations. Approximately 6,700 cy of Turning Basin sediment was used to backfill the dredged area at the Norfolk CSO sediment remediation site. A site closure report was issued in August 1999 (EBDRP, 1999).

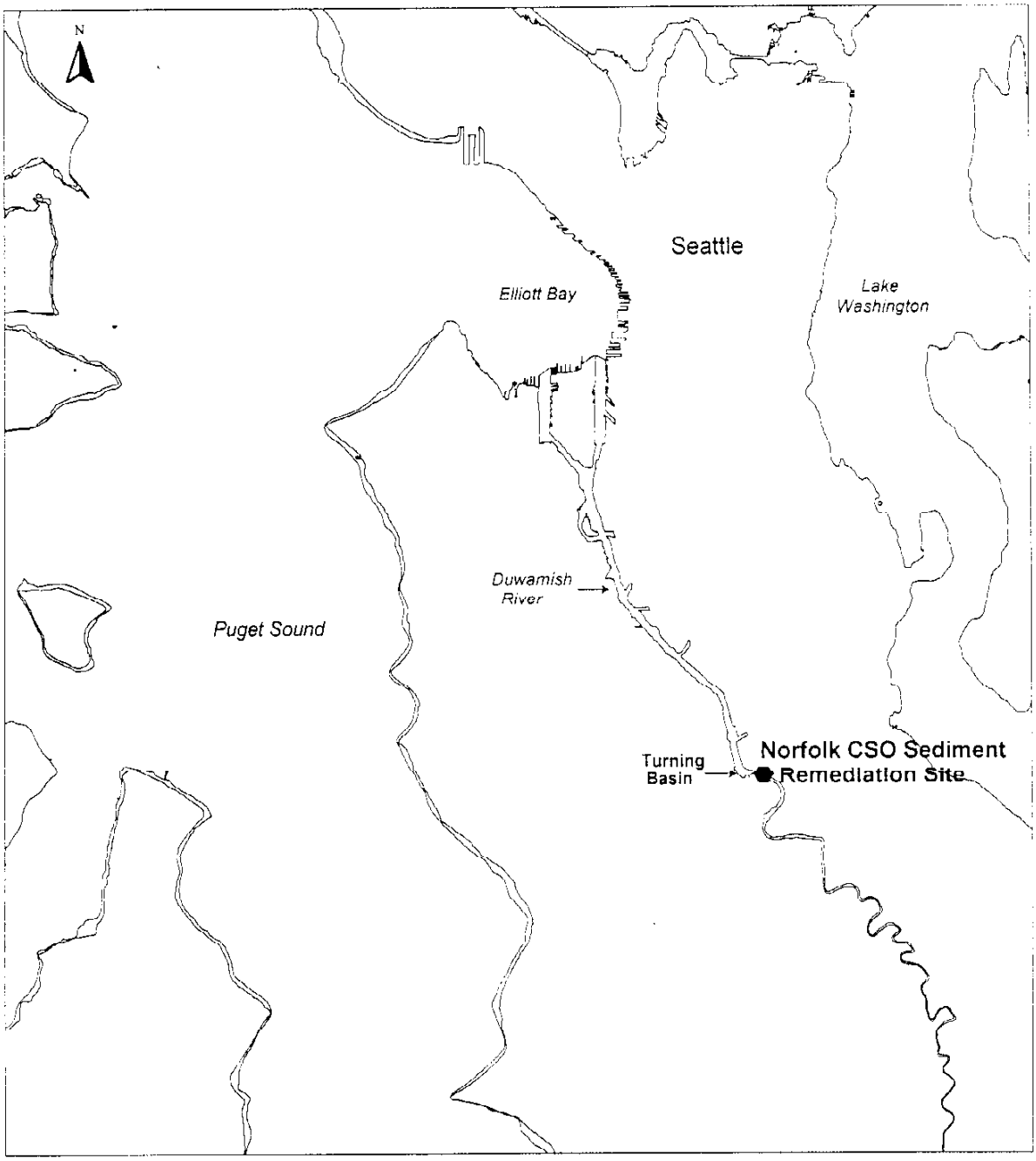
The site hydraulic permit, issued by the Washington State Department of Fish and Wildlife prior to remediation, requires that the site be monitored for a period of five years following remedial activities to evaluate possible recontamination of the backfill sediment as a result of continuing CSO or storm water discharges. To comply with this permit, a five-year monitoring plan was prepared which includes sampling and analysis of surficial sediments from four stations in the backfilled area. Analytical data will allow King County to evaluate the chemical characteristics of the sediment and assess possible recontamination over time. Monitoring activities will be performed in accordance with a sampling and analysis plan addendum prepared by King County (King County, 1999).

1.2 Site Description

The Norfolk CSO sediment remediation site is located in the Duwamish River, above the Turning Basin at approximately river kilometer (km) 10 in the City of Tukwila (Figure 1). The site is located upstream of the river reach maintained for commercial navigation and, as such, has maintained its natural channel as well as some riparian habitat (EBDRP, 1996). The shoreline is characterized by a steeply sloping, erosional bank maintained with large concrete riprap. The bank joins a gently sloping, intertidal mud shoreline that is completely exposed during extreme low tides.

The Norfolk CSO outfall originates at King County's Norfolk Street Regulator Station near South 102nd Street and East Marginal Way in Tukwila (EBDRP, 1996). The outfall structure has a flap gate over the 84-inch discharge pipe and a concrete splash plate that is exposed during normal low tides. The remediation site is located adjacent to the outfall structure and is characterized by exposed, intertidal mud habitat as well as subtidal riverbed. The intertidal zone has been channelized, both by the discharge of the Norfolk CSO and by a storm drain outfall that drains a Boeing Company parking lot adjacent to the CSO outfall.

FIGURE 1
SITE VICINITY MAP
NORFOLK CSO SEDIMENT REMEDIATION



2 SAMPLE COLLECTION

This section describes the post-backfill sampling activities conducted in April 1999 and a post-sampling site survey that was performed in June 1999. All sampling activities were conducted following guidance suggested in the Puget Sound Protocols (PSEP, 1996a and 1998).

2.1 Sample Locations and Station Positioning

Sampling locations were selected and coordinates determined prior to field activities. Sampling locations were selected to assess potential recontamination at the site and evaluate the chemical characteristics of the backfill material at the following locations:

- within the Norfolk CSO outfall channel, inshore of termination of the channel (NFK501);
- the terminus of the Norfolk CSO outfall channel (NFK502);
- the terminus of the Boeing storm drain outfall channel (NFK503); and
- upriver of both the CSO and storm drain outfall channels.

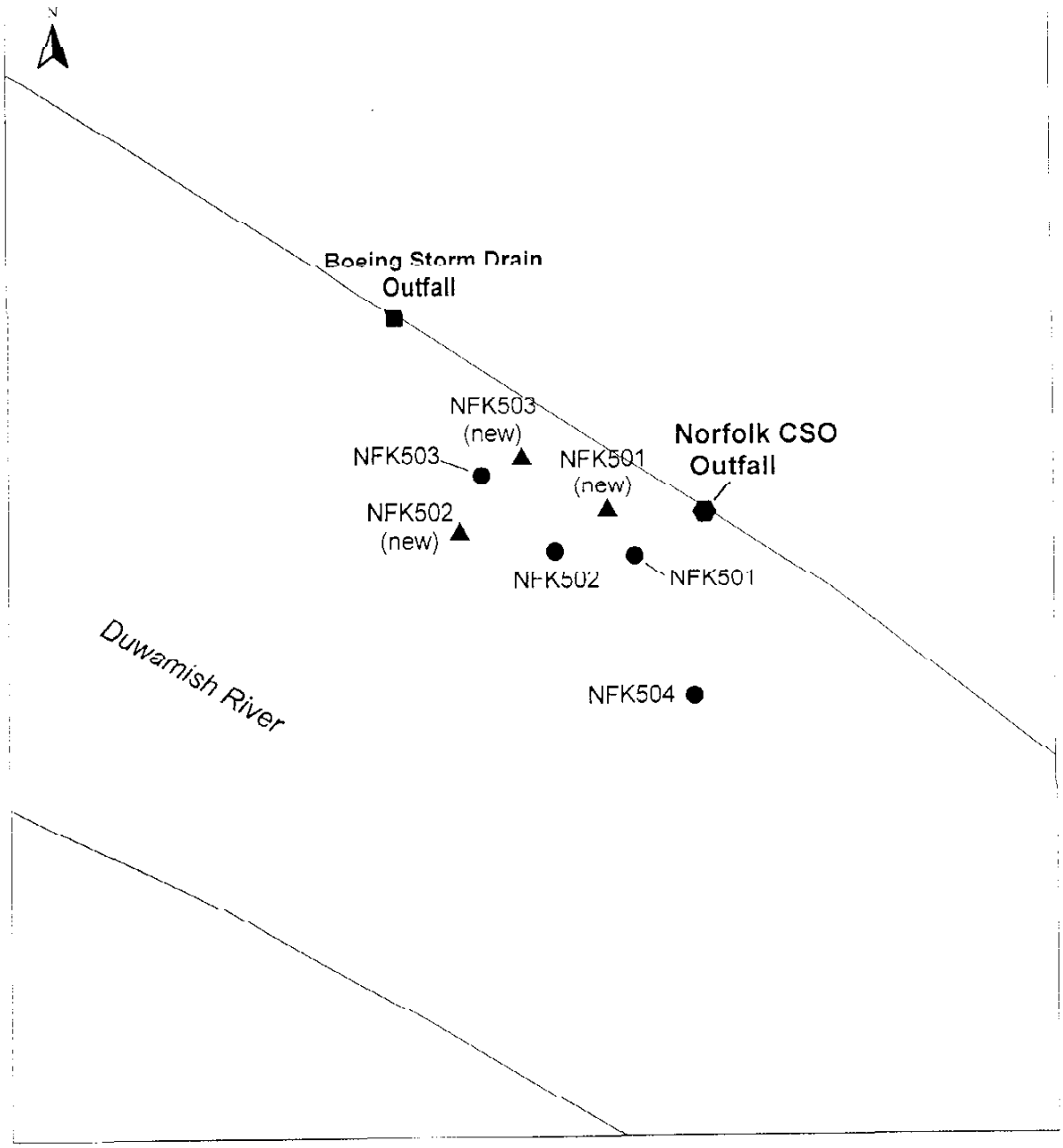
The prescribed station location coordinates are presented in Table 1 and sample locations are shown in Figure 2.

Table 1
Sample Location Coordinates
Norfolk CSO Sediment Remediation Project
Five-Year Monitoring Program
April 1999 Monitoring Data

Station Name	thing (NAD83)		Easting (NAD83)	
NFK501 Prescribed Station	190147		1278595	
NFK501 Grab 1		190147		1278594
NFK501 Grab 2		190153		1278586
NFK501 Grab 3		190149		1278592
NFK502 Prescribed Station	190150		1278560	
NFK502 Grab 1		190147		1278544
NFK502 Grab 2		190160		1278546
NFK502 Grab 3		190154		1278556
NFK503 Prescribed Station	190186		1278524	
NFK503 Grab 1		190193		1278518
NFK503 Grab 2		190194		1278521
NFK503 Grab 3		190196		1278521
NFK504 Prescribed Station	190080		1278625	
NFK504 Grab 1		190090		1278624
NFK504 Grab 2		190078		1278629
NFK504 Grab 3		190081		1278626

Notes
NAD83 - North American Datum, 1983

FIGURE 2
SITE MAP WITH SAMPLE LOCATIONS
NORFOLK CSO SEDIMENT REMEDIATION



Sample station locations were selected to monitor sediment quality in those areas with the greatest potential for recontamination; two stations in the Norfolk CSO channel and one station in the Boeing storm drain channel. The upriver station was selected to provide background or reference data. The station locations were selected based on information provided by site surveys performed prior to remediation. Samples were collected during the first sampling event from these locations. Subsequent visual observations showed the CSO channel had moved and a new survey of the CSO and storm drain channels indicated the need to move some of the stations for future sampling events. Further discussion of this issue can be found in Section 2.3.

Sediment grab samples were collected from the King County research vessel *Chinook*, which is equipped with a differential global positioning system (DGPS). Coordinates, presented in Table 1, were recorded using DGPS for each of the individual grabs as the sampler contacted the river bottom. The DGPS is a satellite-based navigation system that operates using a receiver to calculate ground position by triangulating scrambled data transmitted by a constellation of satellites operated by the Department of Defense (DOD). The ship-board "differential" receiver receives both the scrambled DOD signal and "corrected" signals originating from base stations operated by various agencies including the Coast Guard and King County. System software applies the differential correction and calculates a precise, real-time navigational position.

One composite sediment sample was obtained from each station and submitted for chemical analysis. Each sample was composited from three separate deployments of the grab sampler. The individual grab coordinates are included in Table 1.

2.2 Sample Collection and Handling

Four estuarine sediment samples were collected April 23, 1999 from the Norfolk CSO sediment remediation site. Samples were collected from the top 10 centimeters (cm) of sediment using a stainless steel, modified, 0.1 m^2 Van Veen grab sampler deployed from the *Chinook* via hydrowire. Water depth at the four sample stations ranged between 2 and 2.5 meters on an ebbing tide of approximately 6 feet (referenced to mean lower low water). Between 13 and 16 cm of sediment was recovered in each grab, allowing collection of a sample aliquot from the top 10 cm without sampling sediment that had touched the sides or bottom of the grab sampler. Field data are included in Appendix A.

Samples were comprised of sediment aliquots collected from three individual grabs at each station with an equal amount of material collected from each grab. A sediment aliquot from each grab was collected using a stainless-steel spoon, placed into a stainless-steel bowl, covered with foil, and placed into an ice-filled cooler between grab deployments. After collecting aliquots from three grabs, the sediment sample was thoroughly homogenized and sample aliquots split out into pre-labeled containers. Sample containers were supplied by the King County Environmental Laboratory and were pre-cleaned according to analytical specifications.

A set of sample compositing equipment was dedicated to each station, precluding the need for decontamination of the field gear. The Van Veen grab sampler was decontaminated between stations by scrubbing with a brush and river water followed by a thorough *in situ* rinsing.

Samples were stored in ice filled coolers from the time of collection until delivery to the King County Environmental Laboratory. Samples were delivered under chain-of-custody and were maintained as such throughout the analytical process. A copy of the chain-of-custody is included as part of the quality assurance review narrative found in Appendix B.

Samples were stored frozen (-18°C) by the laboratory until analysis with the exception of samples for particle size distribution (PSD) analysis. PSD samples were stored refrigerated at approximately 4°C. All analyses were conducted by the King County Environmental Laboratory with the exception of PSD, which was analyzed at AmTest, Inc., a subcontracted laboratory accredited by the State of Washington Department of Ecology (Ecology).

2.3 Post-Sampling Survey

After the first monitoring event, visual observation of the intertidal area during a low tide revealed that remedial activities at the site had significantly altered the flow course of both the Norfolk CSO and Boeing storm drain channels. The Norfolk CSO channel now angles downstream instead of going directly offshore and the two channels now intersect prior to the terminus of the CSO channel. In order to continue successfully monitoring the site for possible recontamination, a survey was performed to establish the positions of the new channels and to guide selection of possible sampling locations.

To determine the exact locations of the CSO and storm drain channels, a survey was performed on June 14, 1999 using a Total Station positioning system. The Total Station system consists of a combined theodolite and infrared distance measuring instrument and prism cluster. Five points were surveyed in each of the channels. Based on results of the survey, it was determined necessary to establish new position coordinates for stations NFK501, NFK502, and NFK503.

Old and new coordinates and station descriptions are presented in Table 2 and new station positions are shown in Figure 2. Future monitoring events will use the new stations; however, visual observations will continue during low tides to determine if the channels maintain these new courses. Site photographs, showing channelization at the site, are included in Appendix C.

Approximate distances between the locations sampled during the first event and the new, prescribed station locations are: NFK501 - 32 feet; NFK502 - 46 feet; and NFK503 - 24 feet. Given the fairly short distance between locations and short time period between the placement of the backfill material and the first sampling event, it is felt that the data from this event may still be used as baseline information to which data from subsequent monitoring events may be compared.

Table 2
New Sample Location Coordinates
Norfolk CSO Sediment Remediation Project
Five-Year Monitoring Program
April 1999 Monitoring Data

	Old Coordinates		New Coordinates		
Station Name and Old Description	**Northing**	**Easting**	**Northing**	**Easting**	**New Description**
NFK501 Norfolk CSO outfall channel inshore.	190150	1278610	190170	1278584	Norfolk CSO outfall channel prior to confluence with Boeing storm drain channel.
NFK502 End of Norfolk CSO outfall channel.	190150	1278560	190159	1278514	Delta of Norfolk CSO outfall channel after confluence with Boeing storm drain channel.
NFK503 End of Boeing storm drain channel.	190186	1278524	190195	1278544	Boeing storm drain channel prior to confluence with Norfolk CSO outfall channel.
NFK504 Upriver of CSO and storm drain channels.	190080	1278625	No Change	No Change	No Change

Notes

All coordinates in North American Datum, 1983 (NAD83).

3 SAMPLE ANALYSIS

Four estuarine sediment samples, collected from the Norfolk CSO sediment remediation site, were submitted for analysis of conventional, metal, and organic parameters. This section describes the type of analyses performed, as well as analytical methodologies used and the associated quality assurance/quality control (QA/QC) procedures followed. Unless otherwise specified, all analyses were performed by the King County Environmental Laboratory. Analyses were selected to allow comparison of sediment data to the SMS sediment chemical criteria found in Tables 1 and 3 of Chapter 173-204 WAC.

3.1 Conventionals

Conventional analyses included percent solids, total organic carbon (TOC), and PSD. Percent solids and TOC analyses were performed to provide data necessary to normalize sediment data to dry weight and organic carbon, respectively. TOC analysis will also allow evaluation of possible organic enrichment at the site over time. Both analyses were performed according to methodologies outlined in Standard Methods (APHA, 1998). Percent solids analysis was performed following SM 2540-G, gravimetric determination and TOC analysis was performed following SM 5310-B, high-temperature combustion with infrared spectroscopy. PSD analysis will allow evaluation of the gross physical characteristics of the backfill material and any changes imparted by sedimentation. PSD analysis was performed by AmTest, Inc. of Redmond, Washington according to method ASTM D422, a combination of sieve and hydrometer analyses.

3.2 Metals

Metal analyses included 13 priority pollutant metals, as well as the crustal metals aluminum, iron, and manganese (see Appendix A). SMS regulates eight of the metals included in this suite of analytes; arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc. Metal analysis will allow assessment of potential recontamination at the site over time. With the exception of mercury, all metal analyses were performed following EPA Method 3050A/6010B; strong-acid digestion with inductively coupled plasma optical emission spectroscopy. Mercury was analyzed according to EPA Method 245.5, cold vapor atomic absorption spectroscopy.

3.3 Organics

Organic analyses included base/neutral/acid extractable semivolatile compounds (BNAs) and polychlorinated biphenyls (PCBs) (see Appendix A). Organic analysis will also allow assessment of potential recontamination to the site over time, especially by PCBs and phthalates. BNA analysis was performed following EPA Method 8270 (SW-846), gas chromatography with mass spectroscopy (GC/MS). A separate extract of the sample was analyzed for chlorobenzene compounds using selected ion monitoring (SIM) to achieve the lower detection limits required to meet regulatory criteria for these compounds. PCBs were analyzed by EPA Method 8082 (SW 846), gas chromatography with electron capture detection (GC/ECD). This suite of analytes included all organic compounds regulated under SMS.

3.4 Quality Assurance/Quality Control

All analyses were performed following guidance recommended under Puget Sound Protocols (PSEP 1989, 1996b, and 1996c) including associated QC/QC practices. Laboratory QA/QC practices produced data of sufficient quality to pass QA1 review. Analytical data were reviewed following QA1 guidelines (Ecology, 1989) and flagged with data qualifiers where appropriate. A comprehensive report of analytical data, including qualifier flags is included as Appendix A. The QA1 review narrative is included as Appendix B.

4 ANALYTICAL RESULTS

This section discusses analytical results for the four estuarine sediment samples collected from the Norfolk CSO sediment remediation site and compares the data to sediment criteria specified under SMS (Ecology, 1995). Tables in this section summarize and compare the data to both Sediment Quality Standards (SQS) and Cleanup Screening Levels (CSL).

4.1 Particle Size Distribution

Particle size distribution (also known as grain size distribution) of the four samples is summarized in Table 3. Grain size distribution analysis indicates that the backfill material used during the Norfolk CSO sediment remediation project was comprised of a fairly even-grained homogeneous material. Between 83 and 90% of the grain size distribution of all four samples fell into only two phi sizes; medium to coarse-grained sand.

Table 3
Grain Size Distribution
Norfolk CSO Sediment Remediation Project
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		Percent Distribution			
Phi Size	**Class**	**NFK 501**	**NFK502**	**NFK503**	**NFK504**
p-1.00	Gravel	0.8	0.4	0.4	0.4
p0.00	Sand	3.3	3.0	1.0	3.3
p+1.00	Sand	38	32	28	44
p+2.00	Sand	46	56	55	46
p+3.00	Sand	4.3	4.1	9.0	3.0
p+4.00	Sand	7.0	0.4	1.3	0.4
p+5.00	Silt	1.0	4.7	5.4	2.9

4.2 Conventionals

Conventional analytical results are presented in Table 4 and include percent solids, used to calculate dry-weight sediment concentrations of metal and organic data and total organic carbon (TOC), used to normalize certain organic parameters to organic carbon content.

Percent solids was consistent throughout the four samples, ranging from 76.9 to 77.6%. The organic carbon content was also fairly consistent among the four samples, although the sample collected from station NFK503 showed a slightly higher TOC value, possibly indicating a slight degree of organic enrichment as this station.

Table 4
Sediment Conventionals
Norfolk CSO Sediment Remediation Project
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Conventionals	NFK 501	NFK502	NFK503	NFK504
Solids (%)	76.9	77.4	77.0	77.6
TOC (mg/Kg DW)	1,760	1,210	3,180	1,260

Notes
TOC - Total organic carbon.
mg/Kg DW - Milligrams per kilogram dry weight, based on percent solids analysis.

4.3 Metals

Sediment metal analytical results are summarized in Table 5. Metals data have been normalized to dry weight for comparison to SMS chemical criteria.

Arsenic, cadmium, and silver were either not detected or detected at concentrations just above the MDL in all samples. Reported concentrations of all metals (Appendix A) were at levels indicative of natural, area-wide crustal concentrations (Dexter et al, 1981). Metal concentrations and/or MDL values for those metals regulated under SMS were consistent over all samples and well below SQS chemical criteria.

Table 5
Sediment Metal Concentrations
Norfolk CSO Sediment Remediation Project
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	Concentration (mg/Kg DW)					
Metal	NFK501	NFK502	NFK503	NFK504	SQS	CSL
Arsenic	<MDL (3.3)	3.7	<MDL (3.2)	3.5	57	93
Cadmium	0.20	0.21	<MDL (0.19)	0.21	5.1	6.7
Chromium	12.9	13.0	14.7	12.2	260	270
Copper	11.4	12.2	10.5	11.2	390	390
Lead	4.2	5.0	4.4	4.6	450	530
Mercury	0.055	0.089	0.066	0.072	0.41	0.59
Silver	<MDL (0.26)	<MDL (0.25)	<MDL (0.26)	<MDL (0.24)	6.1	6.1
Zinc	46	43.2	42.1	44.2	410	960

Notes
mg/Kg DW - Milligrams per kilogram dry weight, based on percent solids analysis
<MDL (#) - Analyte not detected above the *method dection limit*. Value is parentheses is the numeric MDL.

4.4 Organics

Organic analytical results are summarized in Tables 6, 7, and 8. Data for ionic organic compounds have been normalized to dry weight for comparison to SMS sediment criteria and are presented in Table 6.

Ionic organic compounds were not detected in any of the samples and the associated MDL values for six of the seven compounds were below SMS sediment criteria (see Table 6). The MDL for 2,4-dimethylphenol (35 µg/Kg dry weight) exceeded the SQS and CSL (29 µg/Kg dry weight) for all samples. Method development at the King County Environmental Laboratory is attempting to lower the current MDL for this compound.

Table 6
Sediment Ionic Organic Concentrations
Norfolk CSO Sediment Remediation Project
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	Concentration (µg/Kg DW)					
Ionic Organics	**NFK501**	**NFK502**	**NFK503**	**NFK504**	**SQS**	**CSL**
Benzoic Acid	<MDL (140)	<MDL (140)	<MDL (140)	<MDL (140)	650	650
Benzyl Alcohol	<MDL (35)	<MDL (35)	<MDL (35)	<MDL (35)	57	73
2,4-Dimethylphenol	**<MDL (35)**	**<MDL (35)**	**<MDL (35)**	**<MDL (35)**	29	29
2-Methylphenol	<MDL (35)	<MDL (35)	<MDL (35)	<MDL (35)	63	63
4-Methylphenol	<MDL (35)	<MDL (35)	<MDL (35)	<MDL (35)	670	670
Pentachlorophenol	<MDL (35)	<MDL (35)	<MDL (35)	<MDL (35)	360	690
Phenol	<MDL (140)	<MDL (140)	<MDL (140)	<MDL (140)	420	1,200

Notes
µg/Kg DW - Micrograms per kilogram dry weight, based on percent solids analysis.
<MDL (#) - Analyte not detected above the *method dection limit*. Value is parentheses is the numeric MDL.
Shaded Cell - MDL exceeds the SQS and/or CSL.

Data for non-ionic organic compounds have been normalized to organic carbon and are presented in Table 7 compared to the SQS and CSL.

Non-ionic organic compounds were not detected in the samples collected from NFK501 and NFK503. Benzo(g,h,i)perylene was detected in the samples collected from NFK502 and NFK 504 at concentrations of 62.6 and 56.0 mg/Kg organic carbon, respectively (Table 7). These concentrations exceed the SQS (31 mg/Kg organic carbon) but not the CSL (78 mg/Kg organic carbon). Hexachlorobenzene was detected in the sample collected from NFK502 at a concentration of 0.80 mg/Kg organic carbon (Table 7), which also exceeds the SQS (0.38 mg/Kg organic carbon) but not the CSL (2.3 mg/Kg organic carbon).

Organic carbon-normalized MDL values for 2-methylnaphthalene, dibenzo(a,h)anthracene, hexachlorobenzene, butyl benzyl phthalate, total PCBs, dibenzofuran, hexachlorobutadiene, and N-nitrosodiphenylamine exceeded the SQS and/or CSL for one or more samples (see Table 7).

Normalization to organic carbon can produce biased results, however, when the organic carbon content of the sample is very low (Ecology, 1992). When the organic carbon content of a sample is near 0.1 or 0.2% (1,000 to 2,000 ppm), even background concentrations of certain organic compounds can exceed the SQS or CSL. TOC concentrations in samples collected from NFK501, NFK502, and NFK504 were all below 0.2% and the TOC concentration in the sample collected from NFK503 was just above 0.3%.

For sediment with a TOC content less than 0.5% (5,000 ppm), Ecology recommends comparing dry weight-normalized, non-ionic organic data to Puget Sound lowest apparent effects thresholds and second lowest apparent lowest effects thresholds (LAET and 2LAET) (EPA, 1988) for a more appropriate evaluation of sediment quality relative to organic compounds (Ecology, 1992). Table 8 presents this comparison.

When comparing these data on a dry weight-normalized basis to the LAET and 2LAET (Table 8), the detected concentrations of benzo(g,h,i)perylene and hexachlorobenzene are well below their respective chemical criteria. Dry weight-normalized MDL values are also below the chemical criteria with the exception of hexachlorobutadiene and N-nitrosodiphenylamine (35 µg/Kg dry weight), which exceed the LAET (11 and 28 µg/Kg dry weight, respectively) but not the 2LAET (120 and 40 µg/Kg dry weight), respectively. The King County Environmental Laboratory is also working on method development to lower these two compounds.

The full list of organic chemicals (72 total) for which these samples were analyzed is included in Appendix A. Chemical criteria for twenty-five of these compounds have not been developed under SMS. It should be noted that these other organic compounds were also not detected in any of the samples.

Table 7
Sediment Non-Ionic Organic Concentrations (Organic Carbon Normalized)
Norfolk CSO Sediment Remediation Project
Five-Year Monitoring Program
April 1999 Monitoring Data

	Concentration (mg/Kg OC)					
	NFK501	NFK502	NFK503	NFK504		
Non-Ionic Organics	TOC 0.18%	TOC 0.12%	TOC 0.32%	TOC 0.13%	SQS	CSL
LPAHs						
Acenaphthene	<MDL (8.0)	<MDL (12)	<MDL (4.4)	<MDL (11)	16	57
Acenaphthylene	<MDL (12)	<MDL (17)	<MDL (6.6)	<MDL (17)	66	66
Anthracene	<MDL (12)	<MDL (17)	<MDL (6.6)	<MDL (17)	220	1,200
Fluorene	<MDL (12)	<MDL (17)	<MDL (6.6)	<MDL (17)	23	79
2-Methylnaphthalene	<MDL (32)	**<MDL (46)**	<MDL (18)	**<MDL (44)**	38	64
Naphthalene	<MDL (32)	<MDL (46)	<MDL (18)	<MDL (44)	99	170
Phenanthrene	11.9	<MDL (17)	<MDL (6.6)	<MDL (17)	100	480
Total LPAH	11.9	<MDL	<MDL	<MDL	370	780
HPAHs						
Benzo(a)anthracene	<MDL (12)	<MDL (17)	<MDL (6.6)	<MDL (17)	110	270
Benzo(a)pyrene	<MDL (20)	<MDL (29)	<MDL (11)	<MDL (28)	99	210
Benzofluoranthenes (Total)	<MDL (32)	<MDL (46)	<MDL (18)	<MDL (44)	230	450
Benzo(g,h,i)perylene	<MDL (20)	**62.6**	<MDL (11)	**56.0**	31	78
Chrysene	<MDL (12)	<MDL (17)	<MDL (6.6)	<MDL (17)	110	460
Dibenzo(a,h)anthracene	**<MDL (32)**	**<MDL (46)**	**<MDL (18)**	**<MDL (44)**	12	33
Fluoranthene	<MDL (12)	<MDL (17)	<MDL (6.6)	<MDL (17)	160	1,200
Indeno(1,2,3-c,d)pyrene	<MDL (20)	<MDL (29)	<MDL (11)	<MDL (28)	34	88
Pyrene	<MDL (12)	<MDL (17)	<MDL (6.6)	<MDL (17)	1,000	1,400
Total HPAH	<MDL	62.6	<MDL	56.0	960	5,300
Chlorobenzenes						
1,2-Dichlorobenzene	<MDL (0.51)	<MDL (0.74)	<MDL (0.28)	<MDL (0.71)	2.3	2.3
1,4-Dichlorobenzene	<MDL (0.51)	<MDL (0.74)	<MDL (0.28)	<MDL (0.71)	3.1	9
Hexachlorobenzene	**<MDL (0.51)**	**0.80**	<MDL (0.28)	**<MDL (0.71)**	0.38	2.3
1,2,4-Trichlorobenzene	<MDL (0.51)	<MDL (0.74)	<MDL (0.28)	<MDL (0.71)	0.81	1.8
Phthalates						
Bis(2-ethylhexyl) Phthalate	<MDL (12)	<MDL (17)	<MDL (6.6)	<MDL (17)	47	78
Butyl Benzyl Phthalate	**<MDL (12)**	**<MDL (17)**	**<MDL (6.6)**	**<MDL (17)**	4.9	64
Di-N-butyl Phthalate	<MDL (20)	<MDL (29)	<MDL (11)	<MDL (28)	220	1,700
Di-N-octyl Phthalate	<MDL (12)	<MDL (17)	<MDL (6.6)	<MDL (17)	58	4,500
Diethyl Phthalate	<MDL (20)	<MDL (29)	<MDL (11)	<MDL (28)	61	110
Dimethyl Phthalate	<MDL (8.0)	<MDL (12)	<MDL (4.4)	<MDL (11)	53	53
Miscellaneous Compounds						
Dibenzofuran	**<MDL (20)**	**<MDL (29)**	<MDL (11)	**<MDL (28)**	15	58
Hexachlorobutadiene	**<MDL (20)**	**<MDL (29)**	**<MDL (11)**	**<MDL (28)**	3.9	6.2
N-Nitrosodiphenylamine	**<MDL (20)**	**<MDL (29)**	<MDL (11)	**<MDL (28)**	11	11
PCBs						
Total PCBs	**<MDL (13)**	**<MDL (18)**	<MDL (6.9)	**<MDL (17)**	12	65

Notes

mg/Kg OC - Milligrams per kilogram organic carbon, based on total organic carbon analysis.

<MDL (#) - Analyte not detected above the *method dection limit* . Value is parentheses is the numeric MDL.

Shaded Cell - Detected concentration or MDL exceeds the SQS and/or CSL.

Table 8
Sediment Non-Ionic Organic Concentrations (Dry Weight Normalized)
Norfolk CSO Sediment Remediation Project
Five-Year Monitoring Program
April 1999 Monitoring Data

	Concentration (µg/Kg DW)					
Non-Ionic Organics	**NFK501**	**NFK502**	**NFK503**	**NFK504**	**LAET**	**2LAET**
LPAHs						
Acenaphthene	<MDL (14)	<MDL (14)	<MDL (14)	<MDL (14)	500	730
Acenaphthylene	<MDL (21)	<MDL (21)	<MDL (21)	<MDL (21)	1,300	1,300
Anthracene	<MDL (21)	<MDL (21)	<MDL (21)	<MDL (21)	960	4,400
Fluorene	<MDL (21)	<MDL (21)	<MDL (21)	<MDL (21)	540	1,000
2-Methylnaphthalene	<MDL (56)	<MDL (56)	<MDL (56)	<MDL (55)	670	1,400
Naphthalene	<MDL (56)	<MDL (56)	<MDL (56)	<MDL (55)	2,100	2,400
Phenanthrene	21	<MDL (21)	<MDL (21)	<MDL (21)	1,500	5,400
Total LPAH	21	<MDL	<MDL	<MDL	5,200	13,000
HPAHs						
Benzo(a)anthracene	<MDL (21)	<MDL (21)	<MDL (21)	<MDL (21)	1,300	1,600
Benzo(a)pyrene	<MDL (35)	<MDL (35)	<MDL (35)	<MDL (35)	1,600	3,000
Benzofluoranthenes (Total)	<MDL (56)	<MDL (56)	<MDL (56)	<MDL (55)	3,200	3,600
Benzo(g,h,i)perylene	<MDL (35)	75.7	<MDL (35)	70.5	670	720
Chrysene	<MDL (21)	<MDL (21)	<MDL (21)	<MDL (21)	1,400	2,800
Dibenzo(a,h)anthracene	<MDL (56)	<MDL (56)	<MDL (56)	<MDL (55)	230	540
Fluoranthene	<MDL (21)	<MDL (21)	<MDL (21)	<MDL (21)	1,700	2,500
Indeno(1,2,3-c,d)pyrene	<MDL (35)	<MDL (35)	<MDL (35)	<MDL (35)	600	690
Pyrene	<MDL (21)	<MDL (21)	<MDL (21)	<MDL (21)	2,600	3,300
Total HPAH	<MDL	75.7	<MDL	70.5	12,000	17,000
Chlorobenzenes						
1,2-Dichlorobenzene	<MDL (0.90)	<MDL (0.89)	<MDL (0.90)	<MDL (0.89)	35	50
1,4-Dichlorobenzene	<MDL (0.90)	0.97	<MDL (0.90)	<MDL (0.89)	110	120
Hexachlorobenzene	<MDL (0.90)	<MDL (0.89)	<MDL (0.90)	<MDL (0.89)	22	70
1,2,4-Trichlorobenzene	<MDL (0.90)	<MDL (0.89)	<MDL (0.90)	<MDL (0.89)	31	51
Phthalates						
Bis(2-ethylhexyl) Phthalate	<MDL (21)	<MDL (21)	<MDL (21)	<MDL (21)	1,300	1,900
Butyl Benzyl Phthalate	<MDL (21)	<MDL (21)	<MDL (21)	<MDL (21)	63	470
Di-N-butyl Phthalate	<MDL (35)	<MDL (35)	<MDL (35)	<MDL (35)	1,400	5,100
Di-N-octyl Phthalate	<MDL (21)	<MDL (21)	<MDL (21)	<MDL (21)	420	2,100
Diethyl Phthalate	<MDL (35)	<MDL (35)	<MDL (35)	<MDL (35)	48	73
Dimethyl Phthalate	<MDL (14)	<MDL (14)	<MDL (14)	<MDL (14)	71	160
Miscellaneous Compounds						
Dibenzofuran	<MDL (35)	<MDL (35)	<MDL (35)	<MDL (35)	540	700
Hexachlorobutadiene	**<MDL (35)**	**<MDL (35)**	**<MDL (35)**	**<MDL (35)**	11	120
N-Nitrosodiphenylamine	**<MDL (35)**	**<MDL (35)**	**<MDL (35)**	**<MDL (35)**	28	40
PCBs						
Total PCBs	<MDL (22)	<MDL (22)	<MDL (22)	<MDL (22)	130	1,000

Notes

µg/Kg DW - Micrograms per kilogram dry weight, based on percent solids analysis.

<MDL (#) - Analyte not detected above the *method dection limit*. Value is parentheses is the numeric MDL.

Shaded Cell - MDL exceeds the LAET and/or 2LAET.

5 FUTURE MONITORING

Sampling and analysis completed in April 1999 was performed to establish baseline sediment conditions of the backfill surface material shortly after placement at the Norfolk remediation site. The next two sampling events will occur in October 1999, at the end of the first dry season and in April 2000, at the end of the first wet season. These next two sampling events will help to evaluate any differences in chemical characteristics of surface sediments after varying flow regimes. During monitoring years two through five, samples will be collected and analyzed on an annual basis, in April of each year. Station locations will remain the same unless discharge channels change over the course of the monitoring period.

Future monitoring events will include collection of two discrete samples from each of the four established locations. One sample will be collected from the top two cm of sediment and analyzed to evaluate the chemical characteristics of recently deposited material. Another sample will be collected from the top ten cm to evaluate the chemical characteristics of the sediment over the entire biologically active zone. The five-year monitoring schedule is shown below.

- April 1999 - Establish baseline conditions (4 stations, 1 sample at each).
- October 1999 - End of first dry season (4 stations, 2 samples at each).
- April 2000 - End of first wet season and year one (4 stations, 2 samples at each).
- April 2001 - Year two monitoring event (4 stations, 2 samples at each).
- April 2002 - Year three monitoring event (4 stations, 2 samples at each).
- April 2003 - Year four monitoring event (4 stations, 2 samples at each).
- April 2004 - Year five (final) monitoring event (4 stations, 2 samples at each).

6 SUMMARY AND CONCLUSIONS

Four estuarine sediment samples were collected in April 1999 from the Norfolk CSO sediment remediation site within a month after completion of remedial activities. Samples were collected from the surface of backfill material placed at the site and analyzed to establish a baseline chemical characterization of the material. Analytes included sediment conventionals along with metal and organic parameters required under SMS criteria. Station locations were established based on the location of the CSO and storm drain flow channels that existed prior to remediation. Visual observation of the intertidal area and a survey of the flow channels after sample collection resulted in relocation of three stations to meet project objectives.

Based on sample analytical results, the baseline conditions of the backfill material can be characterized by:

- a fairly even-grained, medium to coarse sand with high percent solids and low organic carbon content;
- metals concentrations that are well below the SQS sediment criteria; and
- a lack of organic chemicals with the exception of trace amounts of hexachlorobenzene (one site) and benzo(g,h,i)perylene (two sites), that were well below the LAET sediment criteria (dry-weight normalized).

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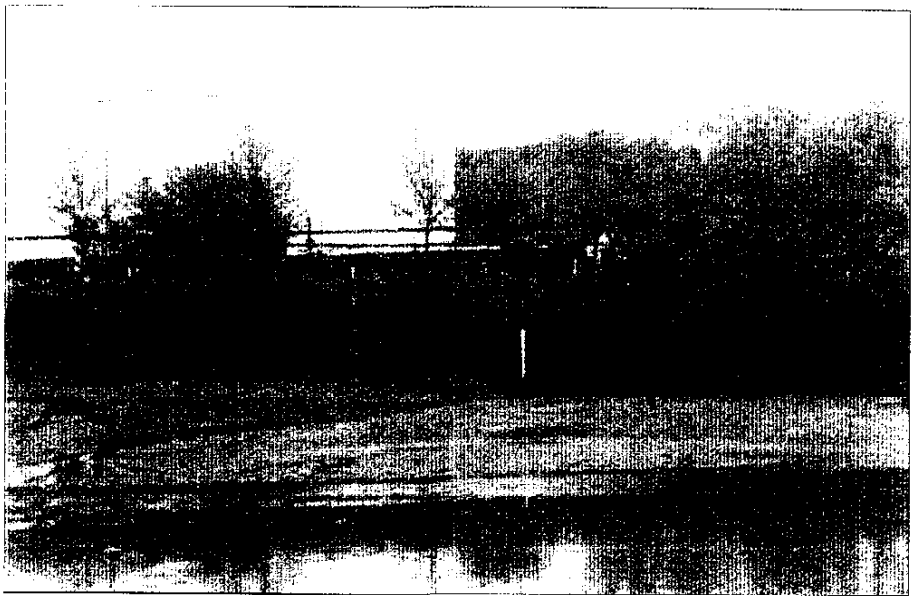
Norfolk CSO outfall at a moderate low tide.

Norfolk CSO outfall at a very low tide, showing channelization.



Norfolk CSO outfall and channel from west side of the Duwamish River. Note the Boeing storm drain channel at the left.